ADVANCED INTERIOR HEAD IMPACT ANALYSES AT VOLVO CARS SAFETY CENTRE

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ABSTRACT – The occupant protection in a car crash is a key during the design of a car. To help protection of occupant safety during interior head impact, National Highway Traffic Safety Administration (NHTSA) revised the requirements of Federal Motor Vehicle Safety Standard 201 regarding upper interior head impact (FMVSS201U). The revised requirement FMVSS201U has to be fulfilled for each new vehicle program released year 2003, or later. In a certification report to NHTSA, the car manufacturer is required to document the status of each vehicle program that is to be sold in the US. The report is based on physical tests with a Free Motion Head Form (FMH) fired against different targets of the upper interior with a specified velocity.

At Volvo Cars Safety Centre, both laboratory tests and CAE (Computer Aided Engineering) simulations are used to provide compliance with this head impact regulation. In order to automate the CAE work, an automatic procedure was developed involving the pre-processing tool ANSA, and the post-processing tool mETA. The algorithm of the FMVSS201U positioning tool in ANSA works in consistency with the regulations. Furthermore, ANSA provides the user with automatically generated target points and automatic multi positioning of the FMH at the target points. In mETA the results can be analysed in many different ways. For instance, a huge amount of results can be presented as overviews, as well as results from a single target point can be shown with detailed information.

1. INTRODUCTION

FMVSS201U tool in ANSA and mETA were developed in close cooperation with Volvo Cars Safety Centre in order to be efficient and easy to use. The objective was to automate the CAE work. Volvo Cars Safety Centre has begun to implement the tools for various types of analyses, e.g. for simplified geometry studies as well as for scanning of the upper roof zone with a huge amount of CAE calculations. The FMVSS201U tool in ANSA and mETA are very flexible and it is up to the user to set the limit.

2. BACKGROUND

The algorithm of the FMVSS201U positioning tool in ANSA works in consistency with the regulations, (1) and (2). In 2011 the effect of the US regulation was evaluated by NHTSA, (3). It was found to give a 4.3-percent reduction of overall fatality risk. If all vehicles on the road meet the regulation, it can save up to about 1300 lives per year.

The targeting procedure is considered to be one of the most complex and time consuming testing protocols developed in recent years. The target points at upper pillar trim and side rail are very well defined in the regulations. However, the entire area of the Upper Roof Zone, i.e. 70 % of the upper roof, may have an infinite number of targets. In addition, in the upper roof zone the FMH can have any horizontal angle between 0-360 degrees but always with a maximum vertical angle ruled by the geometry of the upper interior. However, the geometry of the upper interior can be very complex, see the example in Figure 1.

Figure 1 – The upper interior, i.e. upper trim panels and inner roof, can be very complex as in this XC60, Volvo Car Corporation. FMVSS201U tool in ANSA both simplifies the way of targeting the vehicle and how to position the crash impactor FMH.

The weight of the crash impactor FMH is 4.5 kg and it is fired with a prescribed velocity towards the target point inside the car. The first impact must be within the forehead impact zone, see Figure 2. The positioning process starts by determining the horizontal angle and maximum vertical angle. In order to obtain the maximum vertical angle according to the regulation the FMH is rotated upward until the lip, chin or other part of the impactor contacts an interior part of the car. Then the FMH impactor is rotated back, downwards 5 or 10 degrees, depending on where it is impacting. It is also stated that the vertical angle is maximum 50 degrees.

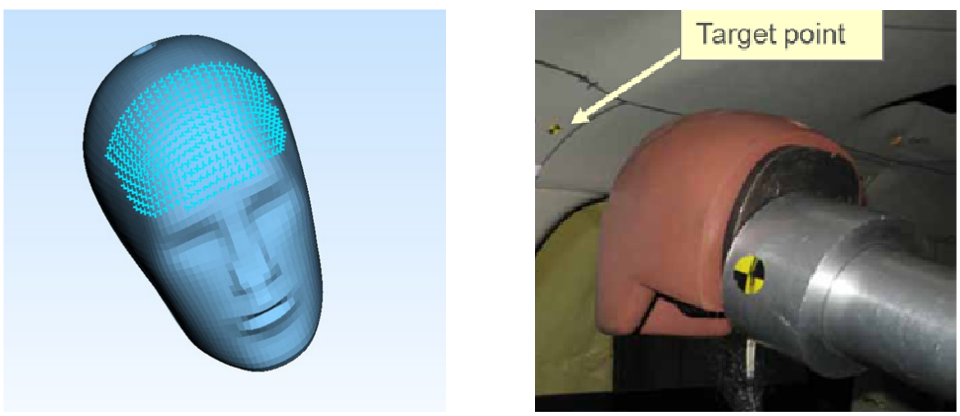

Figure 2 – To the left, a CAE model of a Free Motion Head Form (FMH) showing the Front Head Impact Zone, where the first contact with car must occur. To the right, an FMH about to be positioned at a target point in a physical car.

During the impact a tri-axial accelerometer at the centre of gravity inside the FMH measures its acceleration. The results is put into a performance criteria that consits of two parts. First, Head Injury Criteria (HIC) is a calculation of maximum average acceleration during a specified time (max 36ms). Second, HIC(d) is a transfer function that takes the HIC calculation from the FMH and determines the head injury as if the whole dummy was used. The HIC (d) shall not exceed 1000, which represents the limit of human tolerance. At HIC score 1000 there is an 18 % probability of severe head injury, a 55 % probability of serious head injury and a 90 % probability of moderate head injury, according Prasad and Mertz (4).

2. AUTOMATED TARGETING AND POSITIONING IN ANSA

Automated Targeting

The locations of the target points at upper pillar trim and side rail are very well defined in the regulations and can either be calculated by ANSA, or read from output text-files from Cava, a tool in Catia environment. Automatic targeting for scanning the Upper Roof Zone can easily be produced in a desired grid pattern. A top view of the interior roof filled with target points and an FMH impactor is shown in Figure 3. The target points are created by just giving the start and the end points and the desired amount of targets in-between. The function can be applied on both surfaces and mesh. And as the regulations states, there are no target points on the glass roof.

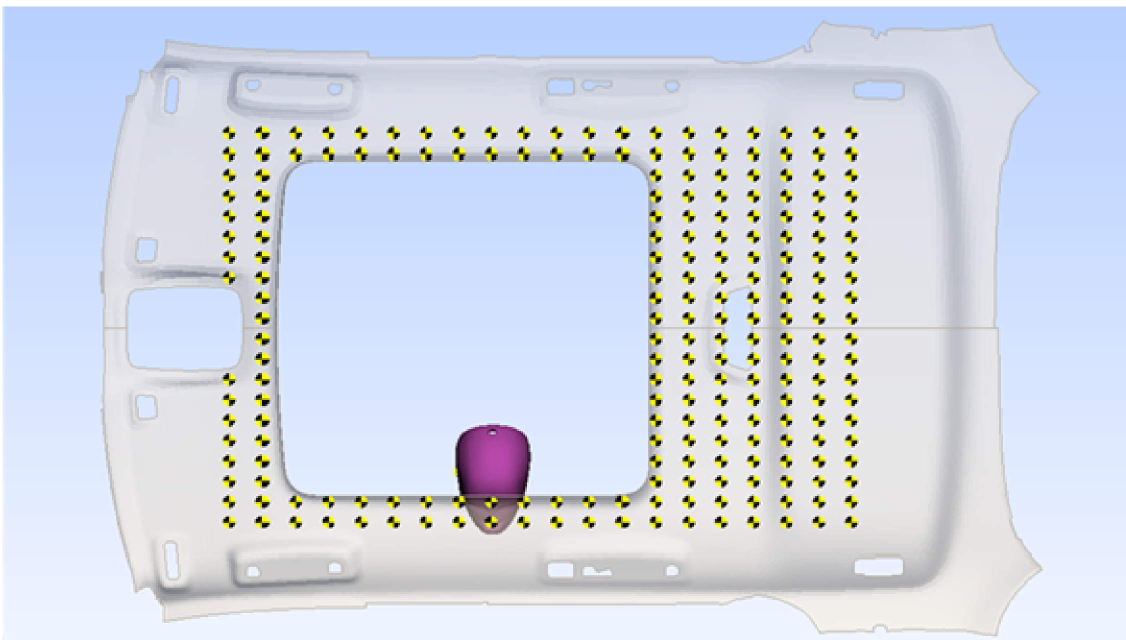

Figure 3 – Targeting the vehicle. This top view of the interior roof is showing an example of an FMH impactor and several target points created by the function automatic targeting in ANSA. The amount and location of points can easily be distributed.

With the functions automatic targeting in ANSA the user can design various set up of calculations. Beside the described distribution of target points in the upper roof zone, there are other ways to add target points. Robustness studies can automatically be generated with the function for circle of points, i.e. around a predefined target point the user gives the desired radius of the circle and number of points on the circle. Furthermore, extra circles can be added as wanted. All the target points are projected to the interior surfaces. Finally, various horizontal angles of the FMH impactor can be easily created for one or several single points.

Automated Positioning

The algorithm in ANSA for positioning of the FMH follows the interpretation that has been experienced at the laboratories. That set-up offers conservative strategies to detect worst-case scenarios. In order to find those impact parameters that produce the highest HIC values, the user can apply:

- Automatic positioning at a predefined target point with maximum vertical angle of FMH impactor,
- Automatic positioning in combination with the features in manual positioning in order to create geometry studies when only some styling surfaces are available.

In ANSA the tool for Automatic Positioning can find a new target point adjacent to the original target point if the geometry around the target point is too narrow or complex for the FMH impactor, see Figure 4. If the user wants, a predefined vertical angle can be given as input. Also in this case the tool can find a new target point adjacent to the original target point in order to position the impactor. Furthermore, this can be applied on a huge amount of target points by the use of the function Automatic Multi Positioning. This is extremely useful in complex, narrow geometries of the upper interior and saves a lot of time for the user.

As well, there is an option to limit the relocation of the FMH impactor within the upper roof zone. If you are positioning an impactor outside the upper roof zone the function can be turned off. Finally, the so called Target Point List offers proper order of both input and output, e.g. the forehead impact point is given in local coordinates of the FMH and the necessary transformation files for the LS-DYNA solver is generated.

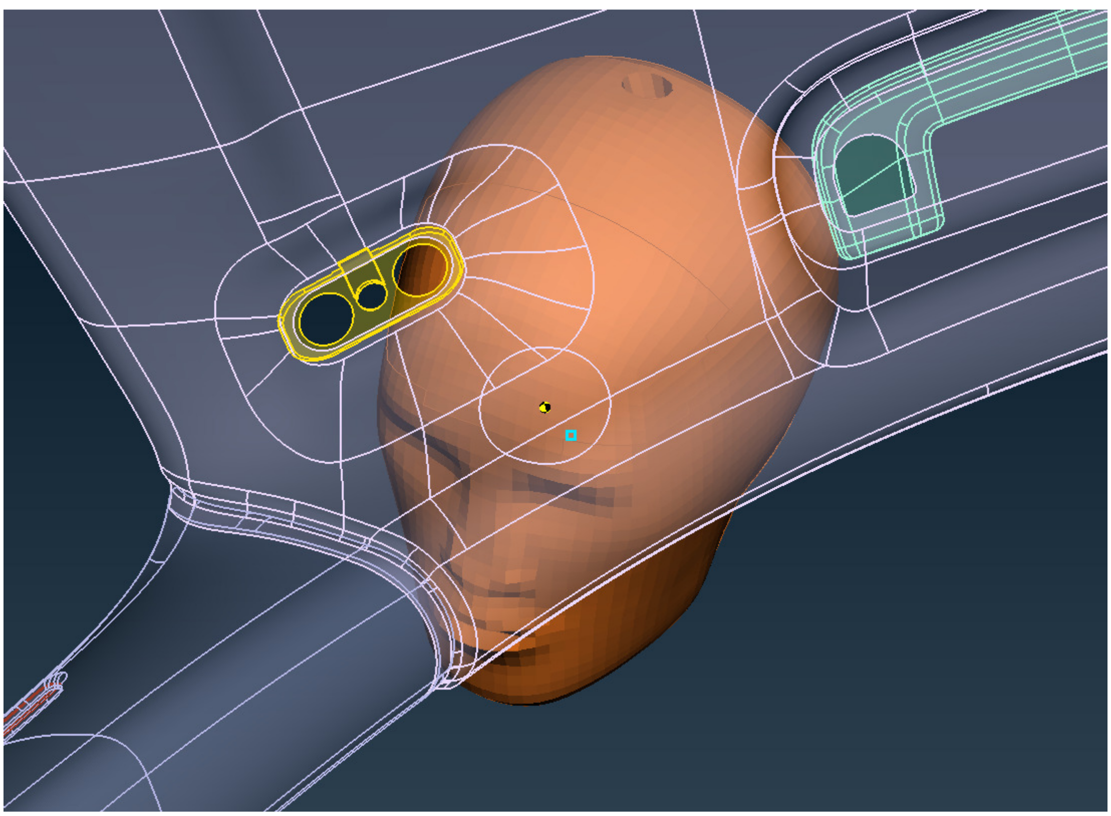

Figure 4 – Automatic Multi Positioning can find a new target point adjacent to the original target point if a final position is not achievable according to the protocol. The new target point proposed by ANSA is coloured blue and the original target point is coloured black–yellow.

3. ANALYSING CALCULATION RESULTS IN META

In mETA the results can be analysed in many different ways. For instance, acceleration-time-graphs according to the test regulations can easily be produced with the FMVSS201U tool in mETA, see Figure 5. Furthermore, results from robustness studies can be presented as overviews, as well as detailed results from a single target point. An overview of CAE results is shown in Figure 6 as a top view of the interior roof. The coloured beams are showing the position and the direction of the FMH impact. The colour and the length of the beams are corresponding to the numeric values of the results.

Finally, reports including graphs, pictures and animations, can be automatically generated by mETA according to the user's specifications. Comparisons between calculation- and laboratory results are also possible.

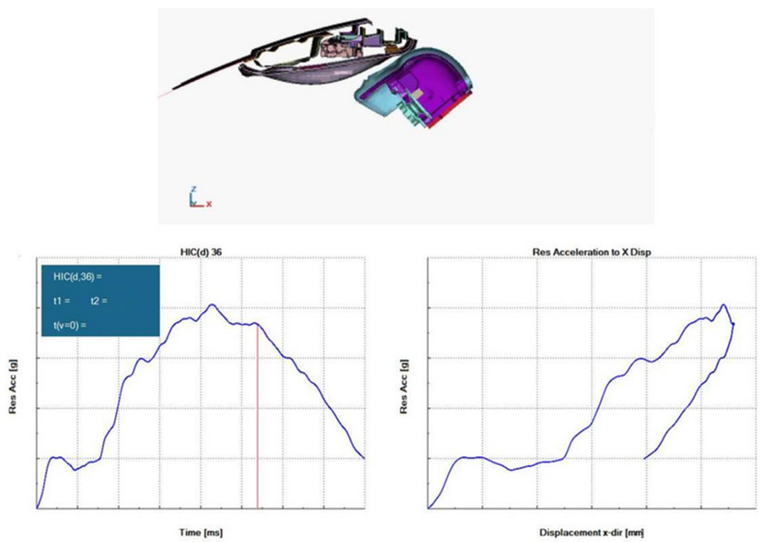

Figure 5 – Results are illustrated by FMVSS201U tool in mETA. First part is a picture showing the location and position of the FMH impactor in the compartment. Second lower part of the picture shows the acceleration-time-graphs according to the test regulations.

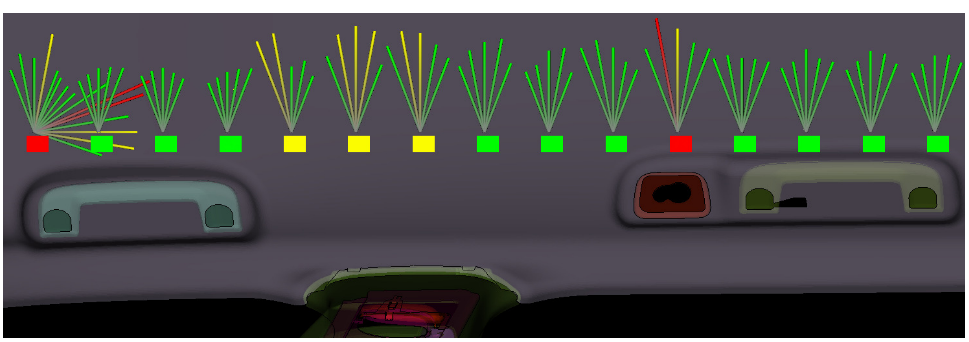

Figure 6 – An overview of results are illustrated by the use of the FMVSS201U tool in mETA. The CAE results on a top view of the interior roof are given as coloured beams representing the position and the direction of the FMH impactor. The colour and the length of the beams are corresponding to the numeric values of the results.

4. CONCLUSIONS

FMVSS201U tool in ANSA and mETA is efficient and easy to use. The functions with automatic targeting and automatic multi positioning were found to be very supportive. The user can design various set up of calculations and speed up the simulation process of the CAE results. The targeting procedure for FMVSS201U is considered to be one of the most complex and time consuming testing protocols developed in recent years. Furthermore, there is an increasing demand for short development times within the automotive industry. Altogether, this has made the automated CAE procedure an indispensable tool in this kind of studies.

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